Proportional control equipment

The equipment of proportional model management is made by many foreign firms. Basically it is a pulsed multichannel equipment, equipped with steering machines. Its circuit solutions can be quite used for the manufacture of equipment in amateur conditions.

Well-known Czech design engineer V. Valenta did just that. He took the equipment of the Teleprop system as a basis, made the necessary changes to it and made his own, modernized version. The description of this equipment will acquaint the reader with how, in practice, they implement one of the principles for constructing a pulsed multichannel radio line of proportional control. The peculiarity of this system is that when transmitting on board a radio-controlled model of information on the position of the control knobs of the command sensors, pulse-width modulation (PWM) is used with time division control channels and a sync gap (Fig. 1). The modulating signal is formed by a clock (T = 20 ms) and multi-phase adjustable multivibrators, differentiating circuits, diode summing cells and an output one-shot.

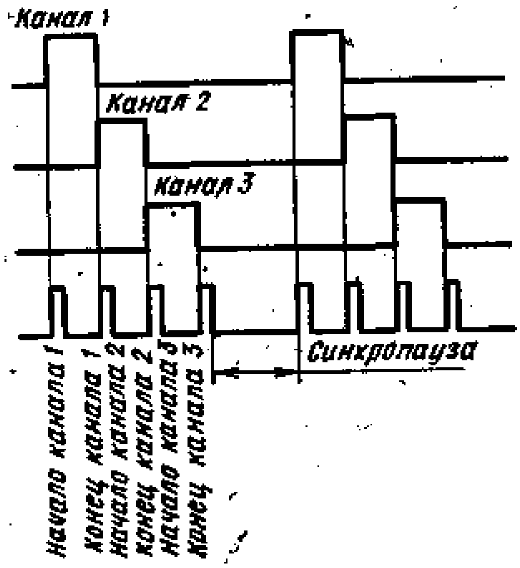
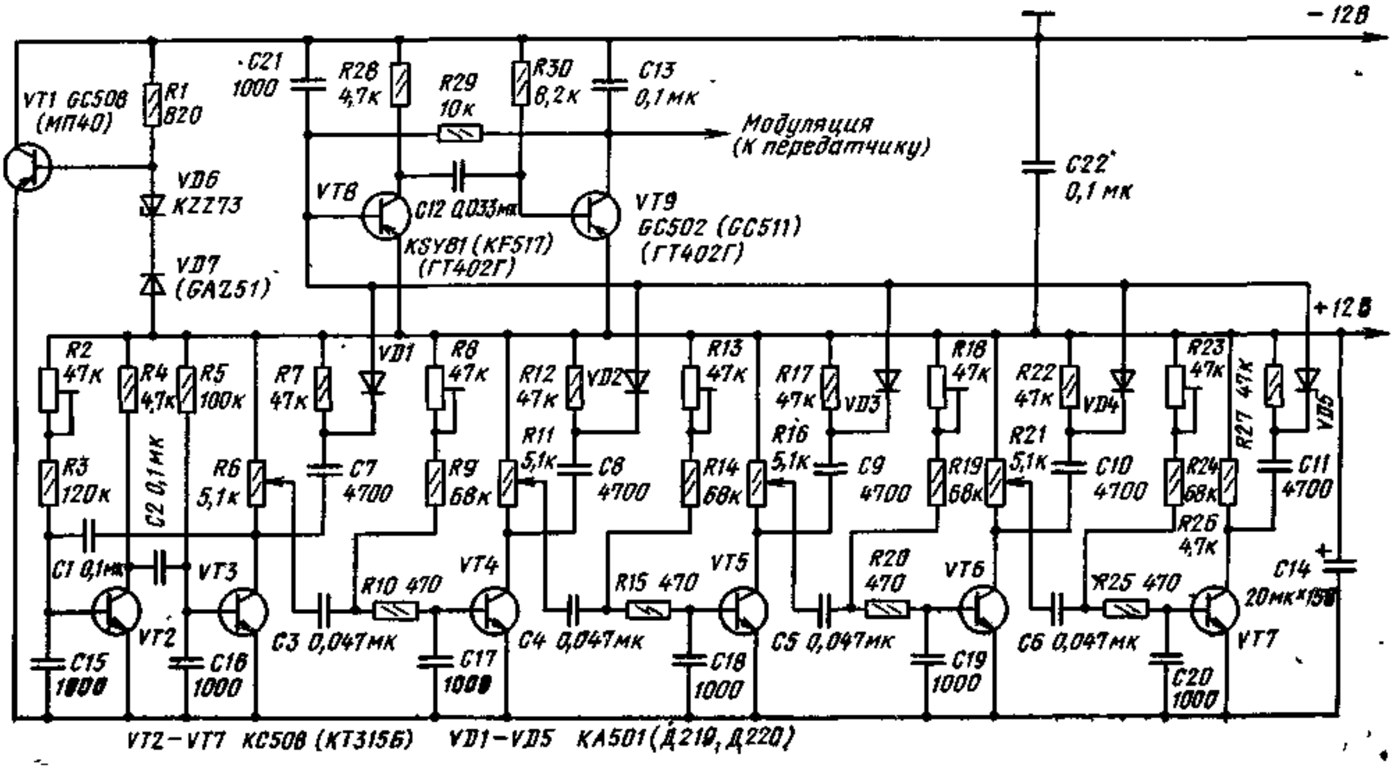


Fig. 1. Diagrams explaining the structure of the pulse sequence in the command channels

In fig. 2 shows a schematic diagram of a four-channel encoder. Multivibrator transistors VT2, VT3 triggers a multi-phase multivibrator, transistors VT4-VT7 which are opened by the base current through resistive circuits.



Suppose that at the initial moment of time transistor VT3 is closed. The capacitor Sz is charged to some voltage, depending on the position of the variable resistor R6. When the multivibrator is switched, the transistor VT3 opens and the voltage of the capacitor C3 closes the transistor VT4.

Transistor VT4 will be closed until the capacitor SZ is discharged through the circuit R8, R9. Thus, the switching time of the transistor VT4 depends on the position of the slider of the variable resistor R6 connected to the control lever of the transmitter, and on the position of the slider of the trimming resistor R8 setting the pulse width at the neutral position of this lever.

To the collector of transistors VT3-VT7 are connected differentiating circuits C7, R7, C8, R12, etc., connected through diodes VD1-VD5 to the national line. A signal is formed on it, consisting of a sync-pause and differentiated short pulses arising at the beginning and end of the channel interval. Diagrams of the collector voltage transistors encoder shown in Fig. 3

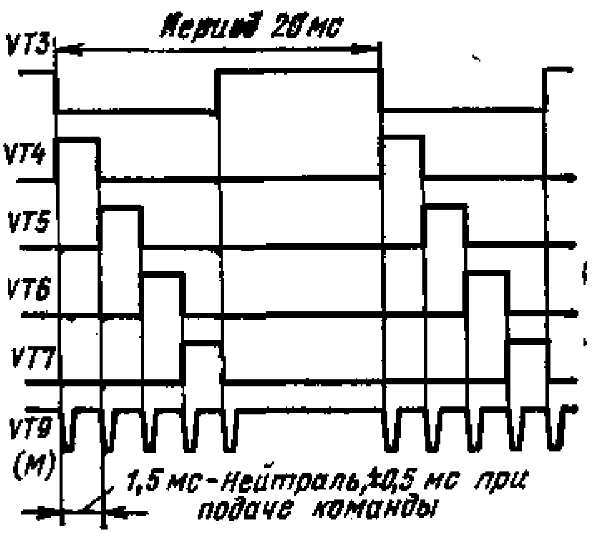


Fig. 3. The voltage plots on the collectors of the transistor encoder

The transmitter modulating transistor operates as a key, which, in the modulation rhythm, connects the supply voltage to the output stage. Since narrow pulses on the assembly line (Fig. 4) have a different duration due to the variation in the ratings of the elements of differentiating circuits, the modulator generates a modulating signal in the form of pulses with certain parameters. For this purpose, a one-shot is designed for transistors VT8, VT9 (Fig. 2), the time constant of which is chosen according to the pulse duration. VT9 transistor simultaneously serves as a modulator.

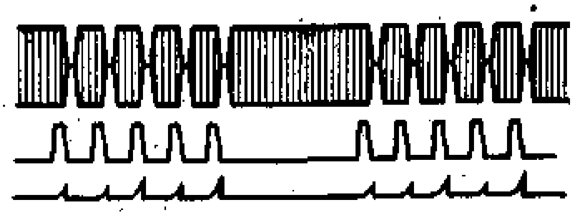


Fig. 4. Pulses on the team line, modulating and modulated signals

To set up the encoder, an oscilloscope with time calibration is needed. A battery with a voltage of 12 V is connected to the encoder. The oscilloscope is used to check the diagrams of the collector voltage (Fig. 3).

Trimmer R2 set the required period duration of the multivibrator (20 ms). The duration of each channel pulse at the neutral position of the lever of the sensor must be 1.5 ms. When translating the command-control lever to the extreme positions, the duration of the channel pulse changes by +0.5 or -0.5 ms, respectively. Thus, the limits of the pulse duration change are 1-2 ms. Trimming resistors R8, R13, R18, R23 set the required pulse duration in each channel at the neutral position of the lever. Mechanisms of variable resistors R6, R11, R16 and R21 are mechanically connected with the levers in the transmitter's transmitter transmitter control unit.

Next, monitor the voltage on the assembly line using an oscilloscope. The collector of the transistor VT9 through a resistor of 100 Ohm is temporarily connected to the common wire (with negative output of the power source). The voltage diagram should correspond to fig. 5. Capacitor C13 is designed to impart to the pulses of a modulating signal a trapezoid shape.

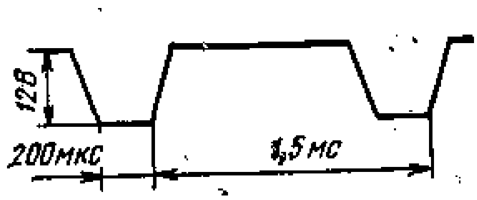


Fig. 5. Plot of voltage at modulator output

This pulse shape reduces the level of harmonics in the high-frequency signal, narrows the emission band and increases the output power of the transmitter. If the pulse duration is different from 200 μs, then it is changed by the selection of the capacitor C12. The terminating resistor with a resistance of 100 ohms is removed; the encoder can be connected to the transmitter.

The transmitter master oscillator (Fig. 6) is made according to a circuit with quartz frequency stabilization. The connection between the steps is inductive. To the collector of the output stage transistor is connected to the P-filter C5, L4, C6, which effectively suppresses the harmonic components. Coil L5 - matching. The recommended antenna length is 1400 m. The following domestic transistors can be used in the transmitter: VT1 series KT315-KT316; KT306A- KT306B, KT603; VT2 - KT603 series. KT904A, KT606A.

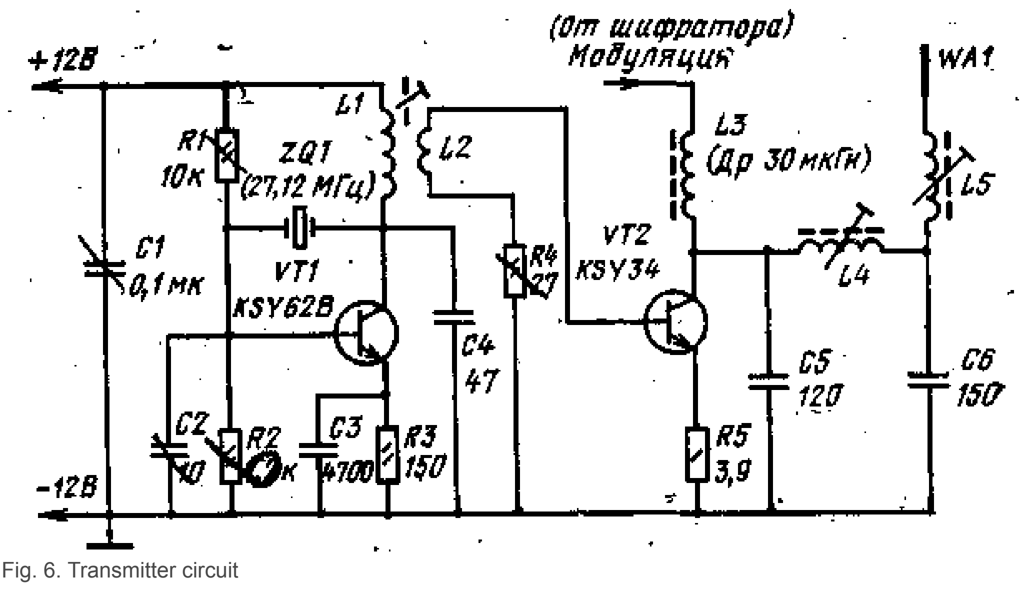


Fig. 6. Transmitter circuit

The coils have the following characteristics: L1 - 14 turns of the PEV-2 0.8 wire on a frame with a diameter of 8 mm with a ferrite trimmer 10 mm long; L2-5-6 turns of mounting wire with a diameter of 0.8 mm. in vinyl chloride or fluoroplastic insulation, L2 is wound over L1; L4-7 turns of the wire sew-2 0.8 on the same frame as L1; L5 -19-25 turns of the PEV-2 0.3 on the same frame (the number of turns is selected depending on the length of the antenna used).

Quartz resonator is used at a frequency of 27.12 MHz ± 0.05%. It is recommended to test the transmitter with a fully deployed antenna. When using the transmitter without an antenna, thermal overload of the terminal transistor is dangerous. The “extension” coil L5 of the antenna, if applied, is adjusted according to the field strength indicator. The transmitter housing is connected to the common wire at one point.

In fig. 7 shows a drawing of a transmitter PCB. The board is shown on the part side. To power the transmitter use a battery of ten nickel-cadmium batteries TsNK-0.45 or TsNK-0.9U2. Three 3336 batteries connected in series can serve as a backup power source.

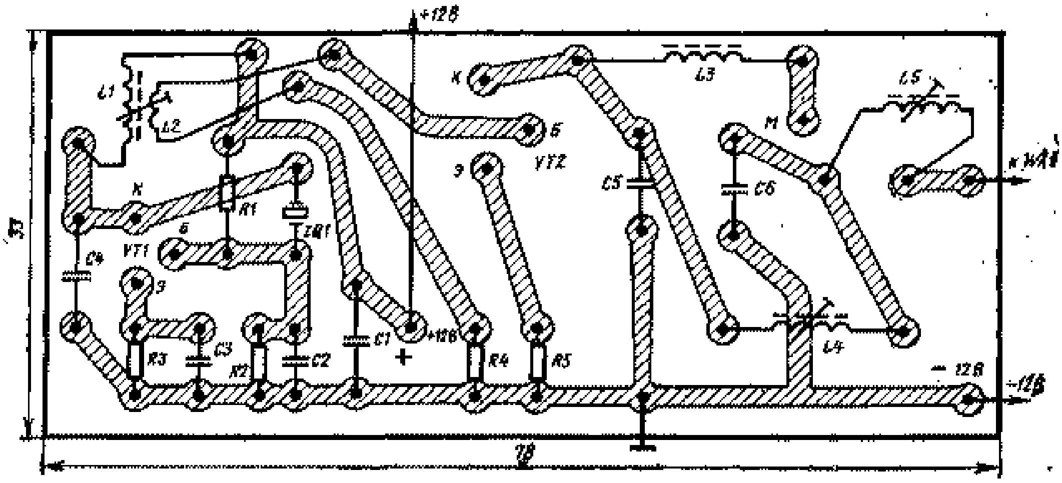


Fig. 7

Finally set up the transmitter after installing it into the case. At the same time adjust the "extension" coil of the antenna, and the transmitter should be in the hands. Transmitter power is approximately 500 mW. It is recommended to install the terminal transistor of the transmitter on the heat sink.

The onboard part of the equipment contains a receiver, a decoder, four identical servo amplifiers and steering cars. The receiver is a superheterodyne tuned to a fixed frequency. To ensure a matchless. Communication the local oscillator of the receiver is collected according to the generator circuit with quartz frequency stabilization. The receiver circuit is shown in fig. 8. At the receiver input, a band-pass filter is applied, which separates the antenna from the input transistor VT1. This increases the selectivity and reduces the return radiation of the local oscillator into the antenna, allows, without restructuring the input circuits, to apply any high-frequency channel in the frequency limits allocated for radio control of models by simply replacing the quartz resonator. The difference in frequency between adjacent channels can be equal to 0.01 MHz.

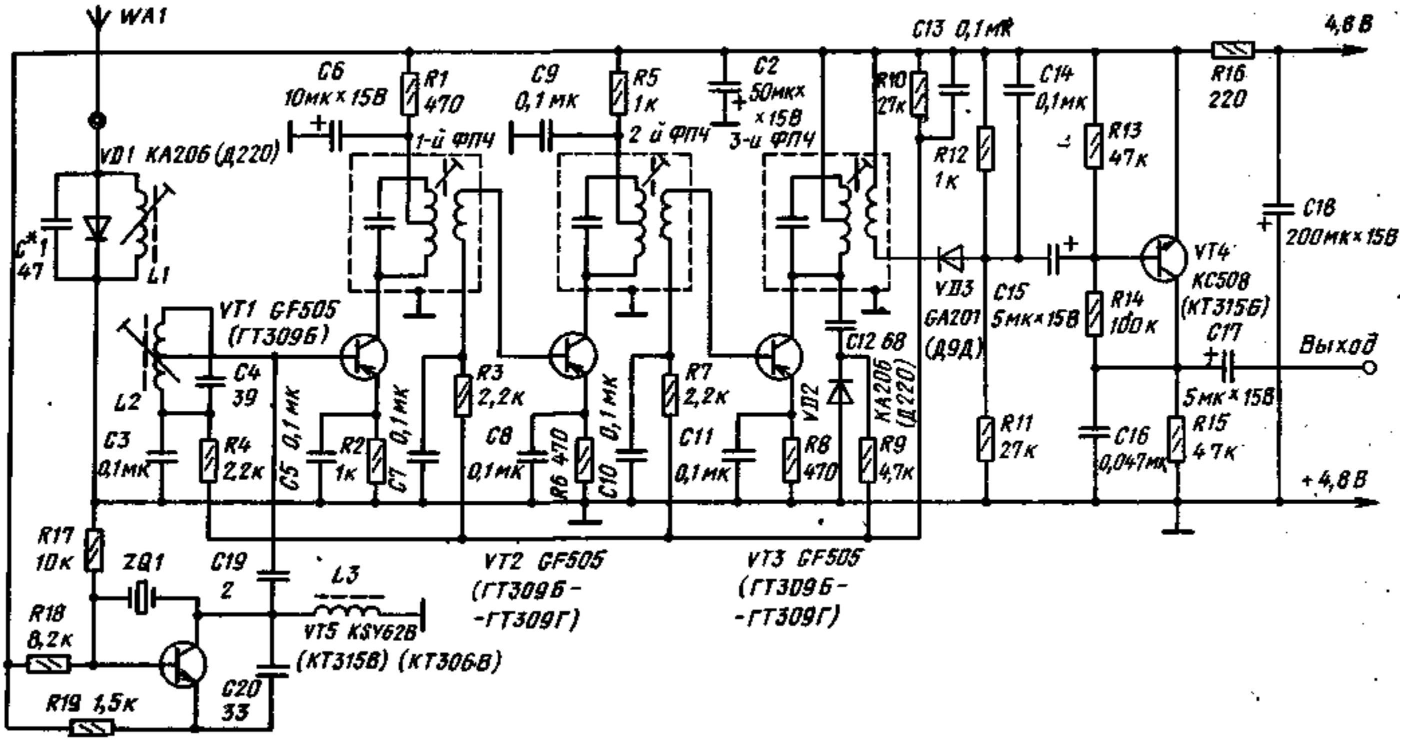


Figure 8 Receiver Diagram

The local oscillator operates at a frequency that is lower than the frequency of the received signal at 465 kHz. Diode VD3 serves as a signal detector, and VD2 is an AGC signal detector. The voltage signal for AGC is removed from the primary winding of the intermediate frequency transformer (intermediate frequency transformers V. Valenta calls intermediate frequency filters, which are single circuits with a coupling coil) and is rectified by a silicon diode, which simultaneously determines the operating point of the mixer and the intermediate frequency amplifier transistors. Accurate operation of the AGC system is important mainly for short distances of the receiver from the transmitter.

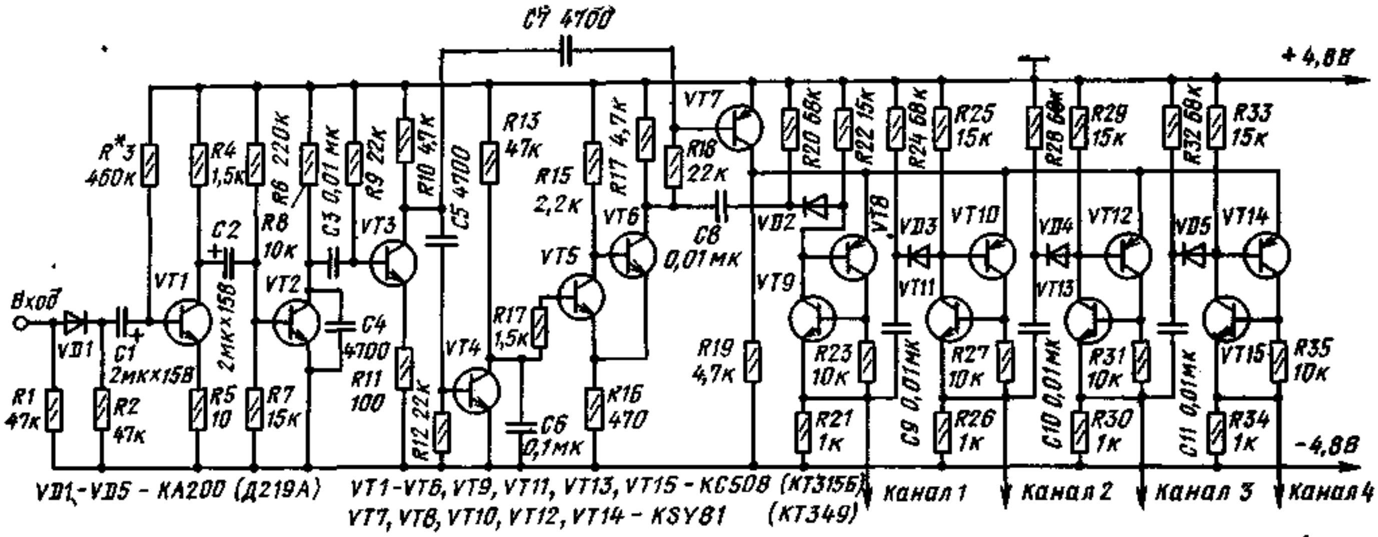
The receiver is designed for the use of finished parts, including intermediate frequency transformers. Intermediate frequency may be in the range from 455 to 468 kHz. The quality indicator of a high frequency transformer is the quality factor. It should be equal to 120-140. The bandwidth of the received signal is 8-10 kHz. Mount the receiver on the same board. Installation can be any. The frameworks of the coils L1 and L2 are 5 mm in diameter. Adjust the coil with ferrite cores, the distance between the axes of the coils is 9 mm (it is necessary to strictly maintain this distance).

The coils are wound with wire sew-2 0.3; L1 contains 10 turns, and L2-13 turns with a tap from the third turn, counted from the end grounded through capacitor C3. The high-frequency choke L3 is wound on an insulating frame with a diameter of 3 mm and a length of 11 mm with the wire sew-2 0.06 turn to turn to fill. The choke can be wound on the resistor MLT-0.5 resistance of at least 100 kΩ.

Adjusting the receiver is to configure the input bandwidth. filter and intermediate frequency transformers. The author recommends configuring the receiver using transmitter signals with a shortened antenna. If you tune the receiver from a generator of standard signals, you need to very accurately know the frequency of the transmitter and tune the generator to it. Before tuning, a 1 m long antenna is connected to the receiver and high impedance telephones to the output.

First, adjust the input filter L1C1 and as the sensitivity increases the transmitter is removed to such a distance that the signal in the phone was heard weakly, and again achieve the maximum when tuning (including the refinement of the transistor VT4 mode). Then adjust the intermediate frequency transformers.

The receiver decoder circuit is shown in fig. 9. The VD1 diode is designed not to miss the signal of interference with an amplitude less than the direct voltage drop across it, i.e., about 0.6 V. The amplitude of the useful signals from the receiver output is approximately 1.1 V.



Receiver decoder circuit

The useful signal is fed to the base of the transistor VT1, working with an inverter. Transistors VT2 and VT3 - amplifiers, pulse shapers. The transistor VT4 in the absence of a signal is closed, and the capacitor C6 is charged to full supply voltage. The first pulse will open the transistor VT4 and discharge this capacitor. The transistors VT5 and VT6 assembled Schmitt trigger, which periodically opens the transistor VT7, and he, in turn, at these moments, passes the voltage pulse to the assembly line. Transistors VT8, VT10, VT12, VT14 are part of the shift register triggers. Through the diode VD2 starts the first register trigger.

Plots of the collector voltage on the decoder transistors and the shape of the channel pulses on. The emitters of transistors VT9, VT11, VT 13, VT15 are shown in fig. 10. The shift register on transistors of various structures is very simple and quite competitive compared to the register on transistors used by a number of foreign firms. In the decoder should use transistors with a coefficient h21e> 50.

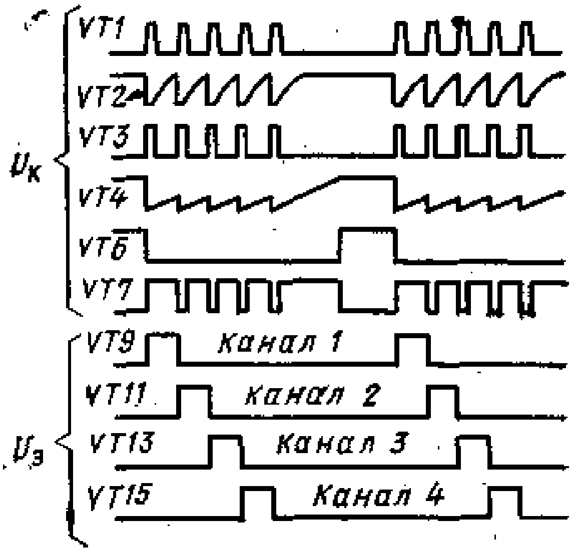


Fig. 10. Plots tense in the decoder

Establishing a decoder is easy. First, the resistor R3 is selected so that the collector of the transistor VT1 has a voltage of 1.5-2.5 V. The resistance of the resistor is changed within 430-820 kΩ.

The final link of the onboard equipment is the electronic unit of the steering machine. The system used steering-cars "Varioprop". The schematic diagram of the electronic unit of the steering machine is presented in Fig. 11. The purpose of the unit, together with the steering engine engine, is to convert the duration of the pulses coming from the decoder into a mechanical deflection of the steering lever, proportional to the duration of the channel pulse, which in turn is proportional to the deflection of the control lever. A single vibrator assembled on transistors VT1 and VT2 and triggered by the front of the input channel positive pulse generates a pulse of negative polarity. Both pulses — positive channel and negative one-shot — come through resistors R13 and R14 to point A for comparison.

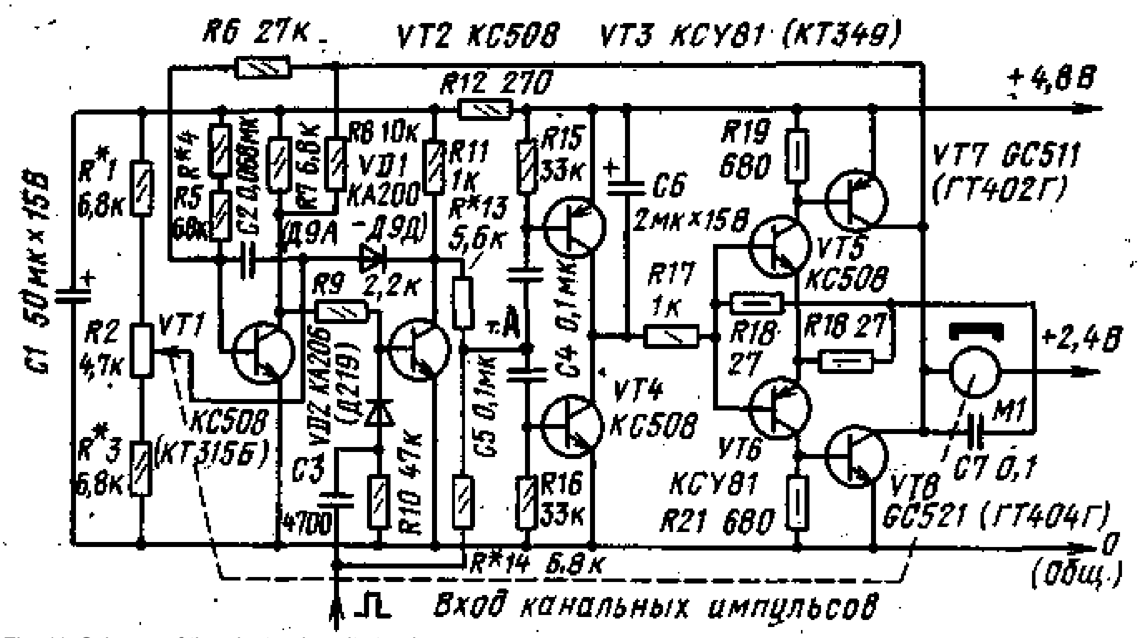


Fig. 11. Scheme of the electronic unit steering gear

When you start the one-shot and neutral position of the steering lever from the collector of the transistor VT2 at point A receives a negative impulse with a duration of 1.5 ms. The pulse duration of the one-shot is controlled by a variable resistor R2, the engine of which is mechanically connected to the output shaft of the steering machine. As a result of the comparison, short impulses are formed, the polarity of which depends on the direction of movement of the pilot-control lever from the neutral position. For the same duration of the compared pulses, the signal to the input of the DC amplifier feeding the steering machine is not received, therefore the shaft of the steering motor does not rotate.

Consider the case when the one-shot pulses are channel. After subtraction, we obtain positive pulses, the duration of which is the smaller, the smaller the difference. In the duration of the compared pulses. Positive pulses open the key on the transistor VT4 and charge the integrating capacitor C6 negative with respect to the midpoint of the power supply voltage, which is fed to the DC amplifier transistors VT6, VT8. The motor Ml is turned on and through the reduction gear moves the rudder shaft and the associated variable resistor slider R2 down the circuit. The duration of the one-shot positive pulse increases and, when it becomes equal to the duration of the channel pulse, the voltage at point A becomes zero. The VT4 transistor is closed, the capacitor C6 is discharged to half the supply voltage,

However, the system containing the integrating links (the capacitor C6 and the electric motor of the steering machine) has inertia. Therefore, it is necessary to turn off the engine a little earlier than the moment when the compared pulses become identical. To do this, introduce negative feedback, because otherwise the mechanical oscillations of the output shaft of the steering machine will begin. Negative feedback voltage from the output of the power steering amplifier is fed to the one-shot input through resistors R6 and R8.

In the case when the one-shot pulse has a longer duration than the channel one, negative pulses are generated at point A. They open the key on the transistor VT3, the capacitor C6 charges positively with respect to the front point of the power supply, the transistors VT5 and VT7 open, and the motor rotates in the opposite direction, moving the variable resistor slider R2 up the circuit. As soon as the input channel pulse is equal in duration to the one-shot pulse, the rotation of the steering motor shaft will stop.

The resistor R12 and the capacitor C1 form a filter in the power supply circuit of the one-shot, necessary for decoupling the power supply circuits of the one-shot, since during operation of the steering gears, the current drops and, therefore, the power supply voltage fluctuations are significant. This leads to a change in the parameters of the one-shot pulses and violates the proportionality of the deflection of the transmitter lever in the steering machine.

The advantages of the described electronic unit in comparison with analog ones include the fact that the final amplifier operates in the key mode open or closed. The time during which the amplifier is in the closed or open state depends on the amplitude of the integrated sawtooth voltage. As soon as the difference in the pulse durations of the channel and the one-shot begins to approach zero, the amplitude of the saw-tooth voltage will become minimal. In this case, the motor receives impulses of short duration, and it, slowing down, brings the steering wheel to the desired position.

The considered principle is widely used in the creation of proportional control equipment. Circuit solutions are distinguished by a great variety, for example, by launching a single vibrator, switching on a variable resistor in mechanical feedback, changing the polarity or amplifying the input channel pulse, replacing the amplifier on VT5, VT6 transistors with a Schmitt trigger, etc.

The electronic unit of the steering machine is mounted on a separate board. All elements are placed on it, except for variable resistor R2 and motor M1. Consider the process of establishing an electronic unit of the steering cars. Selection of resistors R1 and R3 set the maximum rotation of the lever of the steering machine. It is convenient to use the control signals of the transmitter. The input of the electronic unit is connected to the decoder. Flexible conductors connect to the board the leads from the variable resistor R2 and the motor. They turn on the power, but the average battery output is still free. The steering lever is set to neutral. Temporarily instead of resistor R4 connect a variable resistor of 47k0m. On the oscilloscope screen, voltage plots in individual points are observed. They must comply with rice. 12.

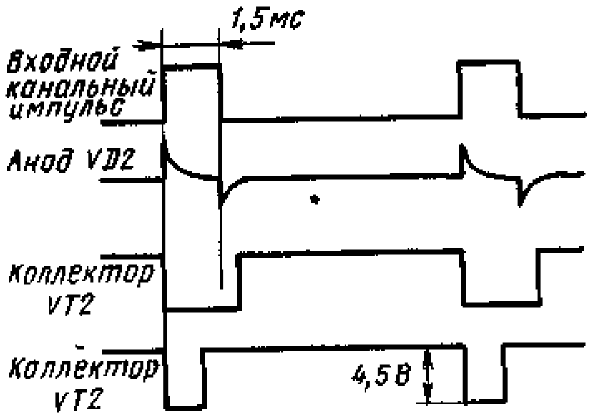


Fig. 12. Stress plots in one-shot

Then connect the oscilloscope to point A and observe the shape of the voltage shown in Fig. 13, a-g. The decoder should receive impulses corresponding to the neutral position of the lever of the command sensor. The duration of these pulses is 1.5 ms.

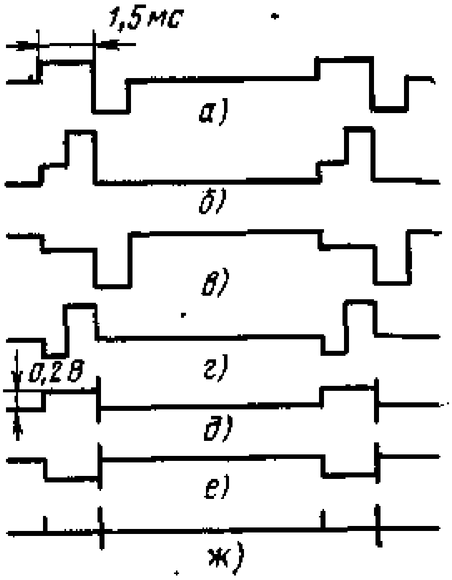


Fig. 13. Stress plot at point A

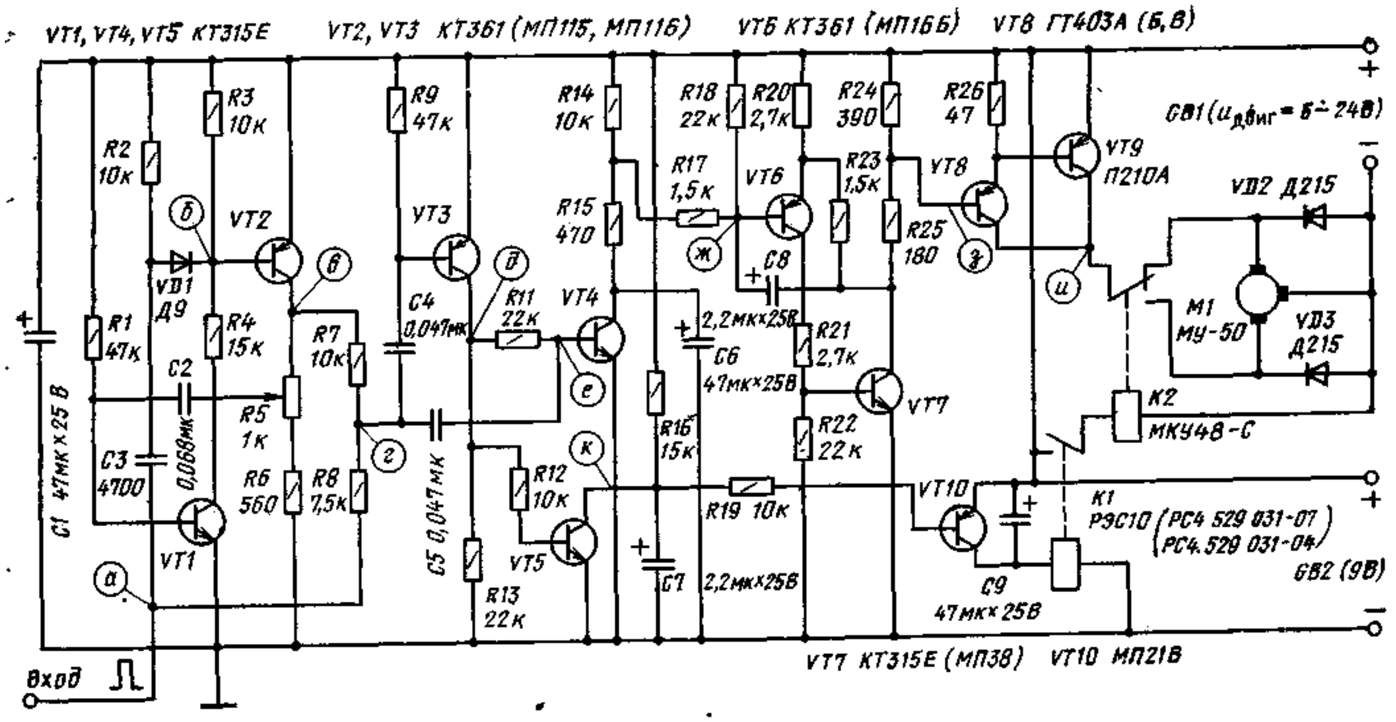
A variable resistor, connected instead of R4, sets such a bias voltage on the base of transistor VT1, so that at point A the waveform corresponds to fig. 13, a or e. Selecting resistors R13 or R14, it is necessary to ensure that the surge voltage is observed only at the beginning and end of the channel pulse (Fig.13, jar). By measuring the resistance of a variable resistor corresponding to this case, a fixed resistor R4 with the same resistance is soldered onto the board. Now connect the middle battery lead. At the same time, the engine of the steering gear should remain in the neutral position, and when the command is changed, that is, when the lever of the transmitter's sending device is moved, it should rotate evenly. Transistors of the ppp structure in the DC amplifier should be used with the base current transfer coefficient h21e> 80.

PROPORTIONAL CONTROL OF SPEED MODEL WITH RUNNING ELECTRIC MOTOR

Most of the auto and ship models are driven by electric motors. The development of the model of proportional control allowed us to solve the problem of reversing the electric motor and smoothly adjusting the rotational speed of its shaft in both directions. Smooth regulation of the speed of movement makes it possible to carry out the model accurately along difficult tracks.

Consider one of the options for proportional control of the rotational speed of the electric motor. The electronic unit of this kind of mechanism converts the duration of the channel pulses into the frequency of rotation of the shaft of the electric motor and ensures its reversal. Pulse systems of proportional multichannel radio control, in which the duration of channel pulses is in the range from 1 ± 0.5 to 2 ± 0.5 ms, are suitable for controlling such a block. The amplitude of the channel pulses should be 4-9 V.

The scheme of the control unit of the frequency of rotation of the motor shaft is shown in fig. 1. Electric motors with a current consumption of 0.2 to 10-L2 A can operate in this unit. The unit is reliable in operation, its feature is the absence of feedback.



Channel decodes of positive polarity come from the decoder to the input of the block. The pulses after differentiation by the capacitor C3 with the front trigger a one-shot on transistors VT1, VT2. On the collector of the transistor VT2 (point b), pulses of negative polarity are calibrated in duration. The voltage plots at different points of the block are shown in Fig. 2. They were removed for the case of supplying the unit with a voltage of 6 V and of the electric motor - 12 V. The duration of the channel pulse is 1 ms and changes in the control process by ± 0.2 ms.

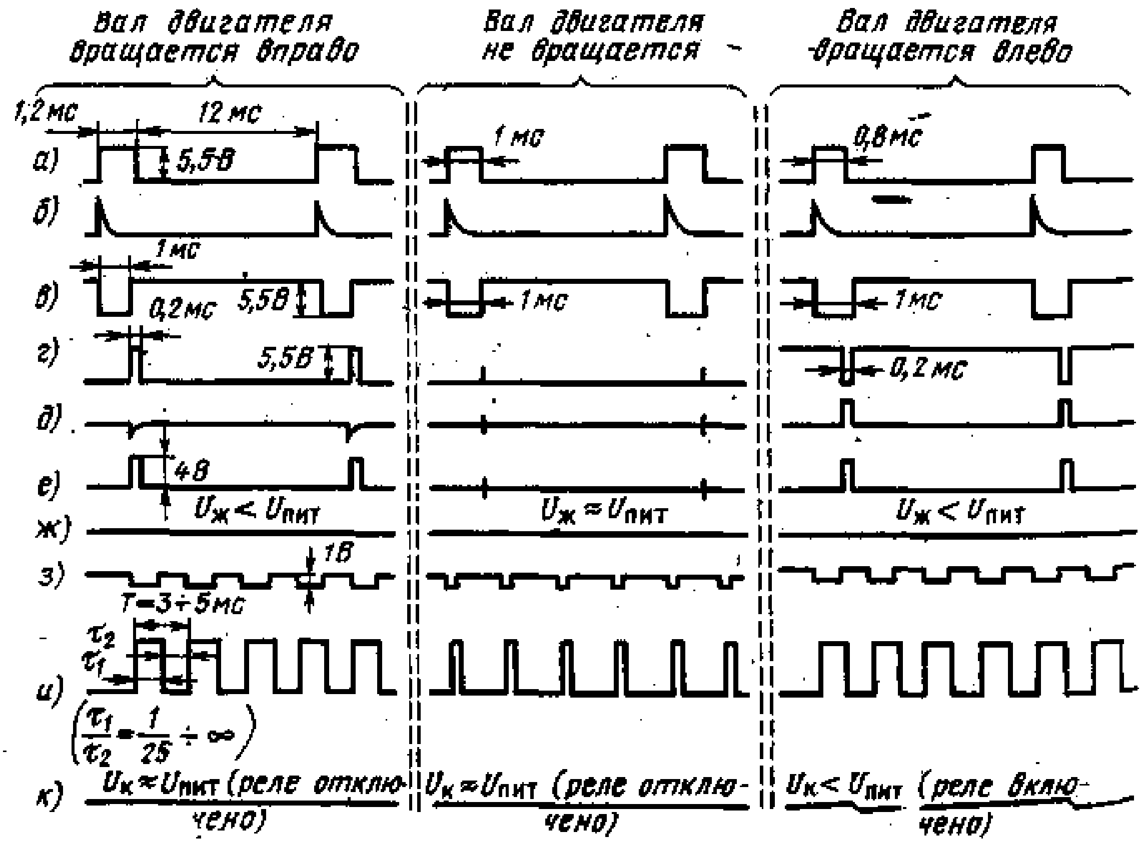


Fig. 2. Stress plots

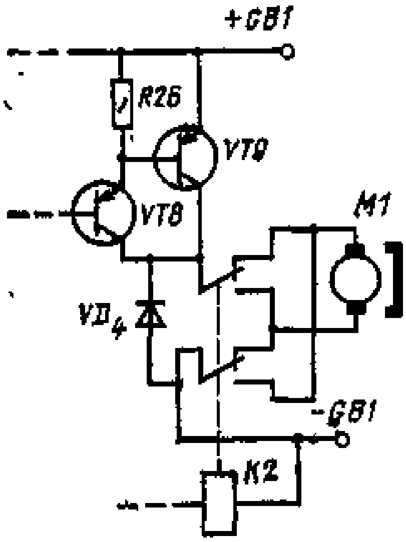
The input channel pulse and the one-shot pulse at point r are added. If the resulting pulse is positive, then passing through the capacitor C5, it will open the transistor VT4 of the integrating stage and change the voltage at the base of the transistor VT6. On transistors VT6 and VT7 assembled multivibrator. Changing the mode of the transistor VT6 causes a change in the frequency and duration of the generated pulses. If "the resulting pulse at the point g is negative, then it is inverted by a cascade on the transistor VT3 and also opens the transistor VT4.

Rectangular pulses from a multivibrator are fed to a power amplifier using transistors VT8, VT9. In the collector circuit of transistor VT9 included running motor, the shaft speed of which depends on the frequency and duty cycle of the pulses. The output transistor of the power amplifier works in the key mode, the losses on it are insignificant. In case of equality in amplitude of the channel pulse and the one-shot pulse, the motor will stop. As the stress diagram shows c. point and, the engine is not completely de-energized, but the power on it does not exceed a fraction of a watt.

If the total pulse at point r becomes negative, the direction of rotation of the motor shaft will change (reversal will occur). Pick up the driving motor contacts of the short-circuit relay, which is triggered after the operation of the intermediate relay K1, which is the load transistor VT10. The

integrating capacitor maintains a constant voltage at the babaz of the VT10 transistor when positive pulses appear at the base of the VT5 transistor. Capacitor C9 smoothes the voltage across the transistor VT10 and prevents the relay K1 from rattling.

In fig. 3 shows a variant of the connection of a running motor with excitation from a permanent magnet.



Adjust the block using an oscilloscope. The process begins with a control node. It is necessary to ensure that the ratio of the pause duration to the duration of the output pulses of the multivibrator changes with a change in the width of the input channel pulse. The output transistor must be completely torn off. A voltmeter is connected between the emitter and collector of transistor VT9. His reading should be close to zero at the maximum voltage on the engine. If the transistor VT9 t opens completely, it should be replaced with another, with a large value of the coefficient h21e, or replace the transistors VT6-VT8 with others, with a large value of this coefficient.

Then achieve accurate operation of the relay K1. If it does not work with a minimum voltage on the motor, then you should choose transistors VT5 and VT10 with a large value of h21e, and also specify the values of the resistors in their basic circuits. With a motor load current up to 4 A, you can choose R25 with a resistance of 300 Ohm; R26-390 Ohm; -VT8-series MP16; VT9-series П214 - П217, П4. The reliability of operation of the unit when controlling powerful electric motors can be enhanced by using two VTs connected in parallel and installed on the heat sinks instead of one VT9 transistor.

"Radio amateur telemechanika". Radio and communication. 1986